Hierarchical Prediction for Lossless Colour Image Compression and Transmission Using OFDM

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Abstract: ***Digital images are usually encoded by lossy compression methods due to their large memory or bandwidth requirements. The lossy compression methods achieve high compression ratio at the cost of image quality degradation. Here presents a lossless color image compression algorithm, based on the hierarchical prediction. For the lossless compression of an RGB image, it is first decorrelated by a reversible color transform and then Y component is encoded by a conventional lossless grayscale image compression method. For encoding the chrominance images, a hierarchical scheme that enables the use of upper, left, and lower pixels for the pixel prediction, whereas the conventional raster scan prediction methods use upper and left pixels. Orthogonal frequency division multiplexing is one of the multi-carrier modulation techniques that transmit signals through multiple carriers. These carriers (subcarriers) have different frequencies and they are orthogonal to each other. Orthogonal frequency division multiplexing techniques have been applied in both wired and wireless communications, such as the asymmetric digital subscriber line and the IEEE 802.11 standard. Here use the orthogonal frequency division multiplexing as the modulation technique for the transmission of the compressed image.***

Keywords: Lossless color image compression, reversible color transform, hierarchical prediction, orthogonal frequency divisionmultiplexing, asymmetric digital subscriber line.

1. Introduction

Recently, the demand and development of multimedia product grows high, which caused to insufficiency of bandwidth of network and storage space of memory device. Therefore, the data compression becomes more and more significant for reducing data redundancy, so can save more hardware space and transmission bandwidth. The demand for higher rate data communication increases, it is clear that a parallel system is capable of carrying more information than a cascade system, because it uses a variety of frequency bands. The advantage of OFDM is that it is robust in frequency selective channels, which result from either communication interferences or multipath fading. Image compression coding is to store the image into bit-stream as compact as possible and to display the decoded image in the monitor as exact as possible. Image compression is an application of data compression that encodes the original image with few bits. When the encoder receives the original image file, the image file will be converted into a series of binary data, which is called the bit-stream. The decoder then receives the encoded bit-stream and decodes it to form the decoded image. If the total data quantity of the bit-stream is less than the total data quantity of the original image, then this is called image compression. The purpose of this project is to develop a hierarchical prediction scheme, while most of existing prediction methods in lossless compression are based on the raster scan prediction which is sometimes inefficient in the high frequency region. In this project design an edge directed predictor to be specific, propose a method that can use lower row pixels as well as the upper and left pixels for the prediction of a pixel to be encoded. For the compression of color images, the RGB is first transformed to YCuCv by an RCT mentioned, and Y channel is encoded by a conventional grayscale image compression algorithm. And the chrominance components are compressed using hierarchical prediction method. After the compression of luminance component and chrominance component this two components and the prediction matrix are transmitted through the channel using the orthogonal frequency division multiplexing.

However, there are many cases where the loss of information or artifacts due to compression needs to be avoided, such as medical, prepress, scientific and artistic images. As cameras and display systems are going high quality and as the cost of memory is lowered, wish to keep our precious and artistic photos free from compression artifacts. Hence efficient lossless compression will become more and more important which leads to motivate to implement such a project as well as the demand for higher rate data communications provides the impetus for this research.

2. Literature Survey

This section provides information about prior works related to image compression and orthogonal frequency division multiplexing.

M.Weinberger, G.Seroussi, and Sapiro [3] proposed that the LOCO-I (LOw COmplexity LOssless COmpression for Images) is the algorithm at the core of the new ISO/ITU standard for lossless and near-lossless compression of continuous-tone images, JPEG-LS. It is conceived as a “low complexity projection” of the universal context modeling paradigm, matching its modeling unit to a simple coding unit. By combining simplicity with the compression potential of context models, the algorithm “enjoys the best of both worlds.” It is based on a simple fixed context model, which approaches the capability of the more complex universal techniques for capturing high-order dependencies. The model is tuned for efficient performance in conjunction with an extended family of Golomb-type codes, which are adaptively chosen, and an embedded alphabet extension for coding of low-entropy image regions.

The paper named information technology-JPEG 2000image coding system-part 1 core coding [5] system proposes in order to promote the wide interoperability of JPEG-2000 code stream, code stream restrictions are introduced. “Code stream Restrictions” have two profiles, profile-0 and profile-1. The case of “No Restrictions” meaning conforming to JPEG-2000 Part-1 standard can be called profile-2. Profile-0 and Profile-1 are defined as follows. Maximum interchange will be achieved for code streams corresponding to Profile-0, and medium interchange for code streams corresponding to Profile-1.

The work done in the paper Lifting-based Reversible color transformations for image compression [9] is a set of color spaces that allow reversible mapping between red-green-blue and luma-chroma representations in integer arithmetic. In this paper H.S Malvar, G.J Sullivan and S.Srinivasan introduced the YCoCg transform and its reversible form YCoCg-R can improve coding gain by over 0.5 dB with respect to the popular YCrCb transform, while achieving much lower computational complexity. Also present extensions of the YCoCg transform for four-channel CMYK pixel data. Thanks to their reversibility under integer arithmetic, these transforms are useful for both lossy and lossless compression. Versions of these transforms are used in the HD Photo image coding technology (which is the basis for the upcoming JPEG XR standard) and in recent editions of the H.264/MPEG-4 AVC video coding standard.

T. Strutz introduced a paper named Adaptive Selection of Color Transformations for Reversible Image Compression [11] which investigates a new family of reversible low complexity colour transformations. It shows that, for a reasonably large set of natural images, there is a colour transform which performs better in the context of lossless image compression than the reversible colour transform defined in the JPEG2000 standard, while having only slightly increased complexity. The optimal selection of a colour space for each single image can distinctly decrease the bit rate of the compressed image. A novel approach is proposed, which automatically selects a suitable colour space with negligible loss of performance compared to the optimal selection.

Wei-yi wei introduced a paper [6] named An Introduction to Image Compression which describes the DCT-based image compression such as JPEG performs very well at moderate bit rates; however, at higher compression ratio, the quality of the image degrades because of the artifacts resulting from the block-based DCT scheme. Wavelet-based coding such as JPEG 2000 on the other hand provides substantial improvement in picture quality at low bit rates because of overlapping basis functions and better energy compaction property of wavelet transforms. Because of the inherent multi-resolution nature, wavelet-based coders facilitate progressive transmission of images thereby allowing variable bit rates. We also briefly introduce the technique that utilizes the statistical characteristics for image compression. The new image compression algorithm called Shape- Adaptive Image Compression, which is proposed by Huang takes advantage of the local characteristics for image compaction. The SAIC compensates for the shortcoming of JPEG that regards the whole image as a single object and do not take advantage of the characteristics of image segments.

X. Wu and N. Memon [4] presnts a context-based, adaptive, lossless image codec (CALIC). The codec obtains higher lossless compression of continuous-tone images than other lossless image coding techniques in the literature. This high coding efficiency is accomplished with relatively low time and space complexities. CALIC puts heavy emphasis on image data modeling. A unique feature of CALIC is the use of a large number of modeling contexts (states) to condition a nonlinear predictor and adapt the predictor to varying source statistics. The nonlinear predictor can correct itself via an error feedback mechanism by learning from its mistakes under a given context in the past. In this learning process, CALIC estimates only the expectation of prediction errors conditioned on a large number of different contexts rather than estimating a large number of conditional error probabilities. The former estimation technique can afford a large number of modeling contexts without suffering from the context dilution problem of insufficient counting statistics as in the latter approach, nor from excessive memory use. The low time and space complexities are also attributed to efficient techniques for forming and quantizing modeling contexts.

The main idea in the paper [10] Improved Reversible Integer to Integer Color Transforms is the integer color transform is a reversible operation that can transform one color coordinate into another one and both the inputs and the outputs are of integer forms. In this paper, improve the integer color transforms derived in previous works. First, relax the constraint that the scaling for each row should be the same. From this, the method of deriving the integer color transform becomes more flexible and can derive the integer color transform with less implementation time and higher accuracy. Moreover, we use the new criterion, bit extension, to measure the performance of the integer color transform and propose a new way for accuracy analysis. With the proposed method, derive the reversible integer RGB-to-YCbCr, KLA, XYZ, UVW, RcGcBc, and YUV transforms with even higher accuracy successfully.

The paper [18] Orthogonal Frequency Division Multiplexing Modulation and Inter Carrier Interference cancellation presented by Yao Xiao have that investigates the Orthogonal Frequency Division Multiplexing (OFDM) technique, wireless channel models, and a pair of new inter carrier interference self-cancellation methods. Orthogonal frequency division multiplexing (OFDM) is one of the multi-carrier modulation (MCM) techniques that transmit signals through multiple carriers. These carriers (subcarriers) have different frequencies and they are orthogonal to each other. Orthogonal frequency division multiplexing techniques have been applied in both wired and wireless communications, such as the asymmetric digital subscriber line (ADSL) and the IEEE 802.11 standard. It is observed that the crosstalk was the severe problem in this system. Although each subcarrier in the principal OFDM systems overlapped with the neighborhood subcarriers, the orthogonality can still be preserved through the staggered QAM (SQAM) technique. However, the difficulty will emerge when a large number of subcarriers are required. In some early OFDM applications, the number of subcarriers can be chosen up to 34. Such 34 symbols will be appended with redundancy of a guard time interval to eliminate inter symbol interference (ISI).

Leonard J and Cimini JR have a paper [17] that proposes analysis and simulation of a technique for combating the effects of multipath propagation and cochannel interference on a narrow-band digital mobile channel. This system uses the discrete Fourier transform to orthogonally frequency multiplex many narrow subchannels, each signaling at a very low rate, into one high-rate channel. When this technique is used with pilot-based correction, the effects of flat Rayleigh fading can be reduced significantly. An improvement in signal-to-interference ratio of 6 dB can be obtained over the bursty Rayleigh channel. In addition, with each subchannel signaling at a low rate, this technique can provide added protection against delay spread. To enhance the behavior of the technique in a heavily frequency-selective environment, interpolated pilots are used. A frequency offset reference scheme is employed for the pilots to improve protection against cochannel interference.

Nick LaSorte, W. Justin Barnes and Hazem H. Refai have a paper [19] named The History of Orthogonal Frequency Division Multiplexing that describes the development of Orthogonal Frequency Division Multiplexing from a historical perspective. A summary of major research milestones are noted that contributed to modern-day OFDM. These contributions include the use of discrete Fourier transforms replacing the analog implementation and addition of cyclic extensions to ensure orthogonality among the sub-channels. Also, channel equalization algorithms to suppress inter-symbol interference and inter-carrier interference, channel estimation through the insertion of pilot tones among data blocks, peak-to-average power ratio reduction, and synchronization techniques are discussed.

3. Block Diagram and Description

The following figure shows the whole process block diagram of the system.

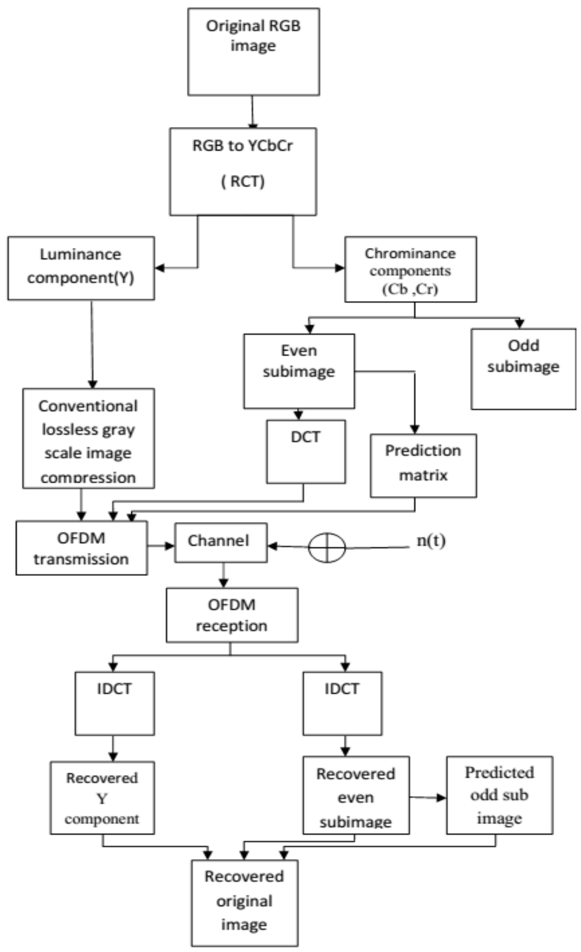

Figure 1: Block diagram of whole process

For the compression of color images, the RGB is first transformed to YCbCr by an RCT mentioned above, and Y channel is encoded by a conventional grayscale image compression algorithm. In the case of chrominance channels (Cb and Cr), the signal variation is generally much smaller than that of RGB, but still large near the edges. For more accurate prediction of these signals, and also for accurate modeling of prediction errors, we use the hierarchical scheme: the chrominance image is decomposed into two sub images; i.e. a set of even numbered rows and a set of odd numbered rows respectively. Once the even row sub image Xe is encoded, can use all the pixels in Xe for the prediction of a pixel in the odd row sub image Xo. So compressed luminance component, DCT compressed even subimage and prediction matrix is transmitted through orthogonal frequency division multiplexing method. Taking the IDCT of received luminance component and received even subimage predict the odd sub image from recovered even subimage. And all of them are combined and getting the recovered original image.

4. Hierarchical Decomposition and Pixel Prediction

The chrominance channels Cu and Cv resulting from the RCT usually have different statistics from Y , and also different from the original color planes R, G, and B. In the chrominance channels, the overall signal variation is suppressed by the color transform, but the variation is still large near the object boundaries. Hence, the prediction errors in a chrominance channel are much reduced in a smooth region, but remain relatively large near the edge or within a texture region. For this, demonstrates a hierarchical decomposition scheme, as shown in Fig 1. Which shows that pixels in an input image X is separated into two subimages: an even subimage Xe and an odd subimage Xo. Then, Xe is encoded first and is used to predict the pixels in Xo. In addition, Xe is also used to estimate the statistics of prediction errors of Xo. For the compression of Xo pixels using Xe, directional prediction is employed to avoid large prediction errors near the edges.

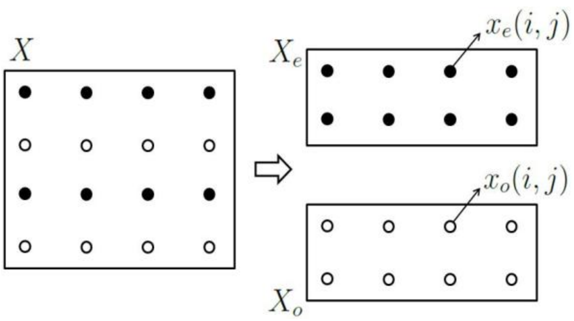

Figure 2: Input image and its decomposition

For each pixel $x_o(i, j)$ in Xo, the horizontal predictor $\hat{x}_h(i, j)$ and vertical predictor $\hat{x}_v(i, j)$ are defined as

$$\hat{x}_h(i,j) = x_o(i, j-1)$$

$$\hat{x}_v(i,j) = round\left(\frac{x_e(i,j) + x_e(i+1,j)}{2}\right)$$

And one of them is selected as a predictor for xo(i, j). With these two possible predictors, the most common approach to encoding is “mode selection,” where better predictor for each pixel is selected and the mode (horizontal or vertical) is also transmitted as side information. However, the vertical predictor is more often correct than the horizontal one when the predictors are defined as above equation because upper and lower pixels are used for the “vertical” whereas just a left pixel is used for the “horizontal.” The horizontal predictor is more accurate only when there is a strong horizontal edge. Hence, the vertical predictor is used for most pixels, and mode selection is used only when the pixel seems to be on a strong horizontal edge.

4.1 Algorithm 1

For implementing the above idea, define a variable for the direction of edge at each pixel dir(i, j), which is given either H or V. Actually, it is given H only when the horizontal edge is strong, and given V for the rest. Deciding dir(i, j) is summarized in Algorithm 1, where it can be seen that the direction is given H only when $|x_o(i, j) - \hat{x}_h(i, j)|$ is much smaller than $|x_o(i, j) - \hat{x}_v(i, j)|$ by adding a constant T1 to the former when comparing them.

If $|x_0(i,j) - \hat{x}_h(i,j)| + T_1 < |x_o(i,j) - \hat{x}_v(i,j)|$ **then**

dir(i,j) ← H

else

dir(i,j) ← V

end if

4.2 Algorithm 2

Based on the directions of pixels, the overall prediction scheme is summarized in Algorithm 2. It can be seen that the mode selection is tried when more than one of dir(i −1, j) or dir(i, j − 1) are H, and the vertical prediction is performed for the rest.

If dir(i-1,j)=H or dir(i,j-1)=H then
Calculate dir(i,j) by Algorithm 1
Encode dir(i,j)
If dir(i,j)=H then
$\hat{x}_o(i,j) \leftarrow \hat{x}_h(i,j)$
else
$\hat{x}_o(i,j) \leftarrow \hat{x}_v(i,j)$
end if
else
$\hat{x}_o(i,j) \leftarrow \hat{x}_v(i,j)$
Calculate dir(i,j) by Algorithm 1
end if

5. Orthogonal Frequency Division Multiplexing

This section gives a review of Orthogonal Frequency Division Multiplexing (OFDM) technique. Orthogonal frequency division multiplexing (OFDM) is one of the multi-carrier modulation (MCM) techniques that transmit signals through multiple carriers. These carriers (subcarriers) have different frequencies and they are orthogonal to each other. Orthogonal frequency division multiplexing techniques have been applied in both wired and wireless communications, such as the asymmetric digital subscriber line (ADSL) and the IEEE 802.11 standard. The crosstalk was the severe problem in this system. Although each subcarrier in the principal OFDM systems overlapped with the neighborhood subcarriers, the orthogonality can still be preserved through the staggered

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QAM (SQAM) technique. Figure 2 shows the modern OFDM system.

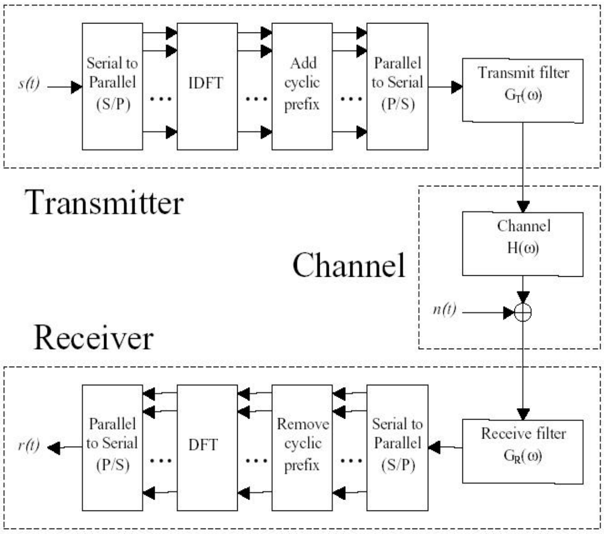

Figure 3: Modern OFDM system

However, the difficulty will emerge when a large number of subcarriers are required. In some early OFDM applications, the number of subcarriers can be chosen up to 34. Such 34 symbols will be appended with redundancy of a guard time interval to eliminate intersymbol interference (ISI). However, should more subcarriers be required, the modulation, synchronization, and coherent demodulation would induce a very complicated OFDM requiring additional hardware cost. In 1971, Weinstein and Ebert proposed a modified OFDM system in which the discrete Fourier Transform (DFT) was applied to generate the orthogonal subcarriers waveforms. Their scheme reduced the implementation complexity significantly, by making use of the IDFT modules and the digital-to-analog converters. In their proposed model, baseband signals were modulated by the inverse DFT (IDFT) in the transmitter and then demodulated by DFT in the receiver.

Therefore, all the subcarriers were overlapped with others in the frequency domain, while the DFT modulation still assures their orthogonality. Windowing technique was introduced to attack the inter-symbol interference (ISI) and inter-carrier interference (ICI) problems.

5.1 Guard Interval and Cyclic Prefix

The cyclic prefix (CP) is the most common guard interval (GI). The GI is introduced initially to eliminate the inter block interference (IBI). Since one block of input data symbols is associated with a single transmitted waveform in an OFDM system, most people refer IBI as ISI. Fig 2 demonstrates how to use the GI to eliminate the ISI. However, multipath fading channel models are concerned in most situations. Therefore, many time-delayed visions of the transmitted waveform might be found at the receiver. Without GI, these waveforms would interfere with each other, just as demonstrated in the top half of Fig 3. Nevertheless, in those cases where the GI was employed, the portions of waveforms received in the GI duration would be totally discarded, as shown in the bottom half of Fig 3. Thus, the ISI could be completely eliminated accordingly. It is noted that the GI duration must be larger than the maximum channel delay time. Otherwise, it could not entirely remove the ISI.

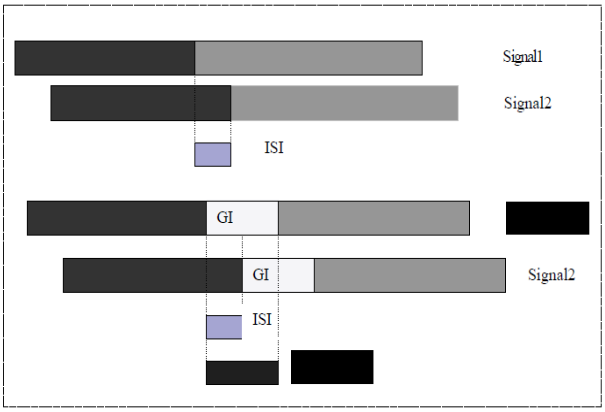

Figure 3: Guard Interval Elimination of the ISI

There are several options for GI. One choice of GI is zero padding. In this scheme, no waveform is transmitted in the GI duration. However, the zero-padded waveform would destroy the orthogonality of subcarriers and results in intercarrier interference (ICI). The cyclic prefix (CP) is a good substitute of the zero-padding GI. In the CP scheme, the GI is a copy of the partial waveform. Based on the fact that the Fourier bases are periodic functions, the orthogonality of subcarriers can be preserved consequently.

6. Results

This chapter gives the results and analysis of the work.

Figure 4: Original and recovered image without transmission through OFDM

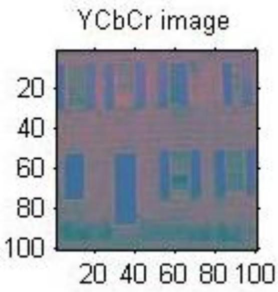

Figure 5: YCbCr image

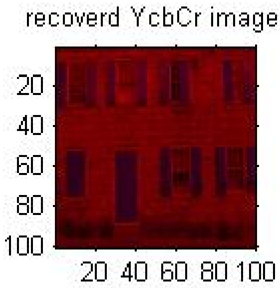

Figure 6: Recovered YCbCr image

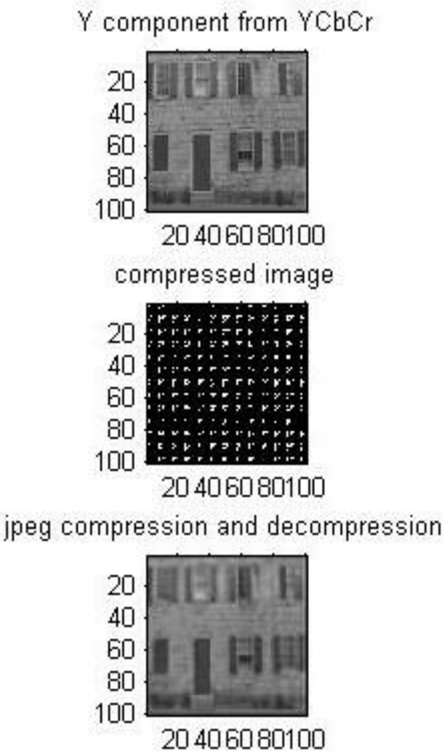

Figure 7: JPEG compression and decompression of Y component

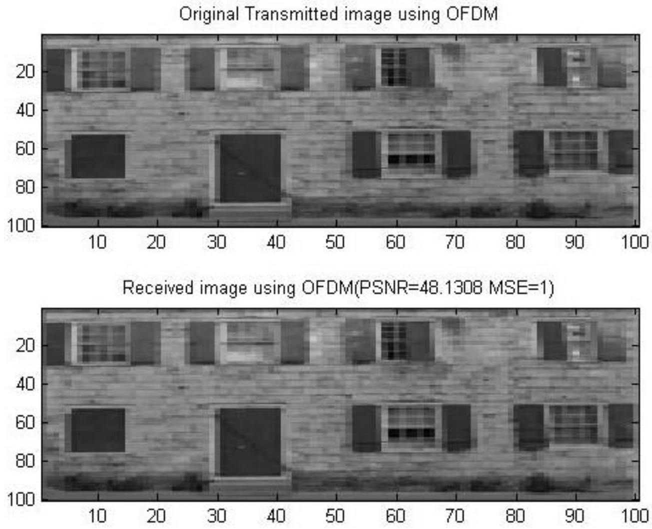

Figure 8: Transmitted and received image using OFDM

7. Conclusion

Presents a lossless color image compression algorithm, based on the hierarchical prediction. For the lossless compression of an RGB image, it is first decorrelated by a reversible color transform and then Y component is encoded by a conventional lossless grayscale image compression method. For the compression of an RGB image, it is first transformed into YC_bC_r color space using an RCT. After the color transformation, the luminance channel Y is compressed by a conventional lossless image coder. Pixels in chrominance channels are predicted by the hierarchical decomposition and directional prediction. In addition to that the Y component, even subimage and prediction matrix are transmitted through the channel using orthogonal frequency division multiplexing. As well as taking the IDCT of received Y component and even subimage, also predicting the odd subimage from even sub image and recovering the original image. The current data compression methods might be far away from the ultimate limits. Interesting issues like obtaining accurate models of images, optimal representations of such models, and rapidly computing such optimal representations are the grand challenges facing the data compression community. Image coding based on models of human perception, scalability, robustness, error resilience, and complexity are a few of the many challenges in image coding to be fully resolved and may affect image data compression performance in the years to come.

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